

Field Measurement

Technical Aspects of the First Generation PN Field Instrument

TSI Nanoparticle Emission Tester Model 3795

Hans-Georg Horn
TSI GmbH, Aachen, Germany

Brian Osmondson,
Jason Johnson
Aaron Avenido
TSI Inc., Shoreview, MN, USA



Overview

- + Purpose & background
- + TSI Model 3795 –technical overview
- + Prototype conformance tests at METAS
 - SR 941.242 requirements and NPET specifications
- + First field measurement results



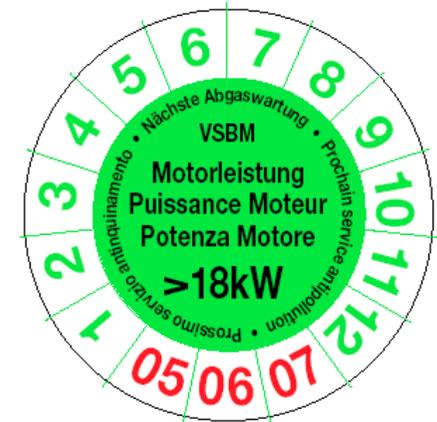
Purpose & Background

- + Swiss ordinance requires diesel particulate filter (DPF) for non-road mobile machinery (NRMM)
 - Test the efficacy of installing DPF
- + Bi-annual test to certify machinery for use
 - Determine if DPF is good or is damaged (e.g. cracked) and needs to be replaced

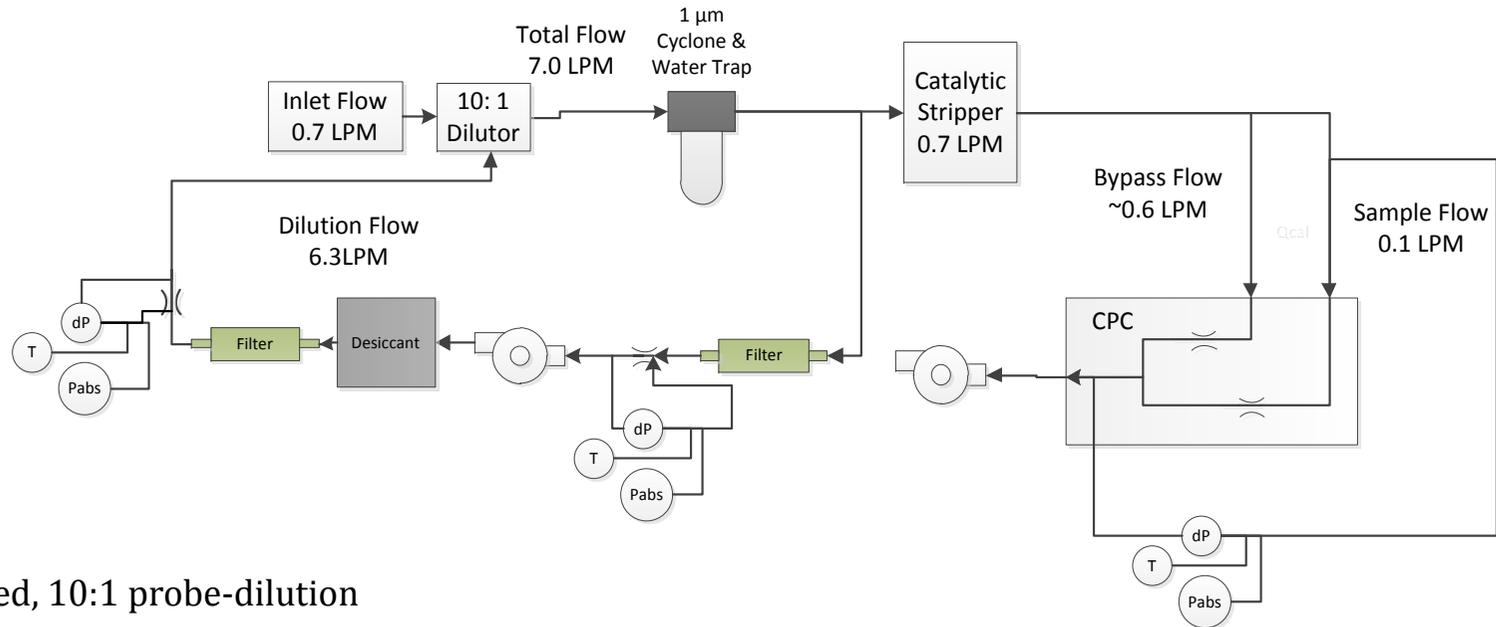


Swiss Regulation SR 941.242

- + Effective Jan. 1, 2013 (latest changes effective March 1, 2014), Switzerland amended the regulation requiring periodic PN emissions testing and compliance for diesel engines
 - Amended the “*Ordinance of the Federal Department of Justice and Police on Exhaust Gas Analyzers*”
- + Candidate instruments must be tested & approved by Federal Office of Metrology (METAS)
 - i.e. “Conformity of Compliance”
- + Measurement procedure refinement is underway, BAFU workshop in April 2014
- + Enforcement expected to start ~January 2015



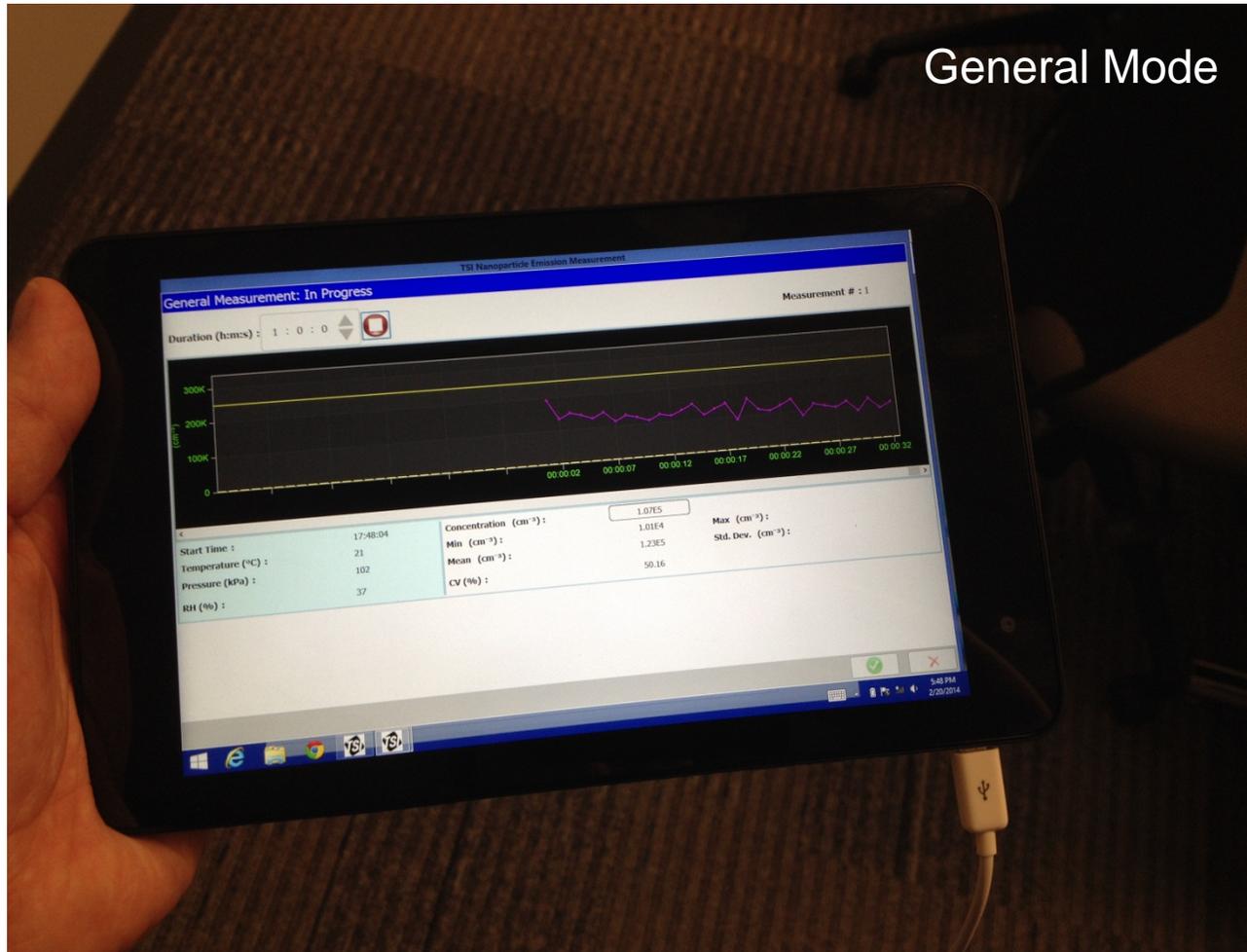
Block Diagram



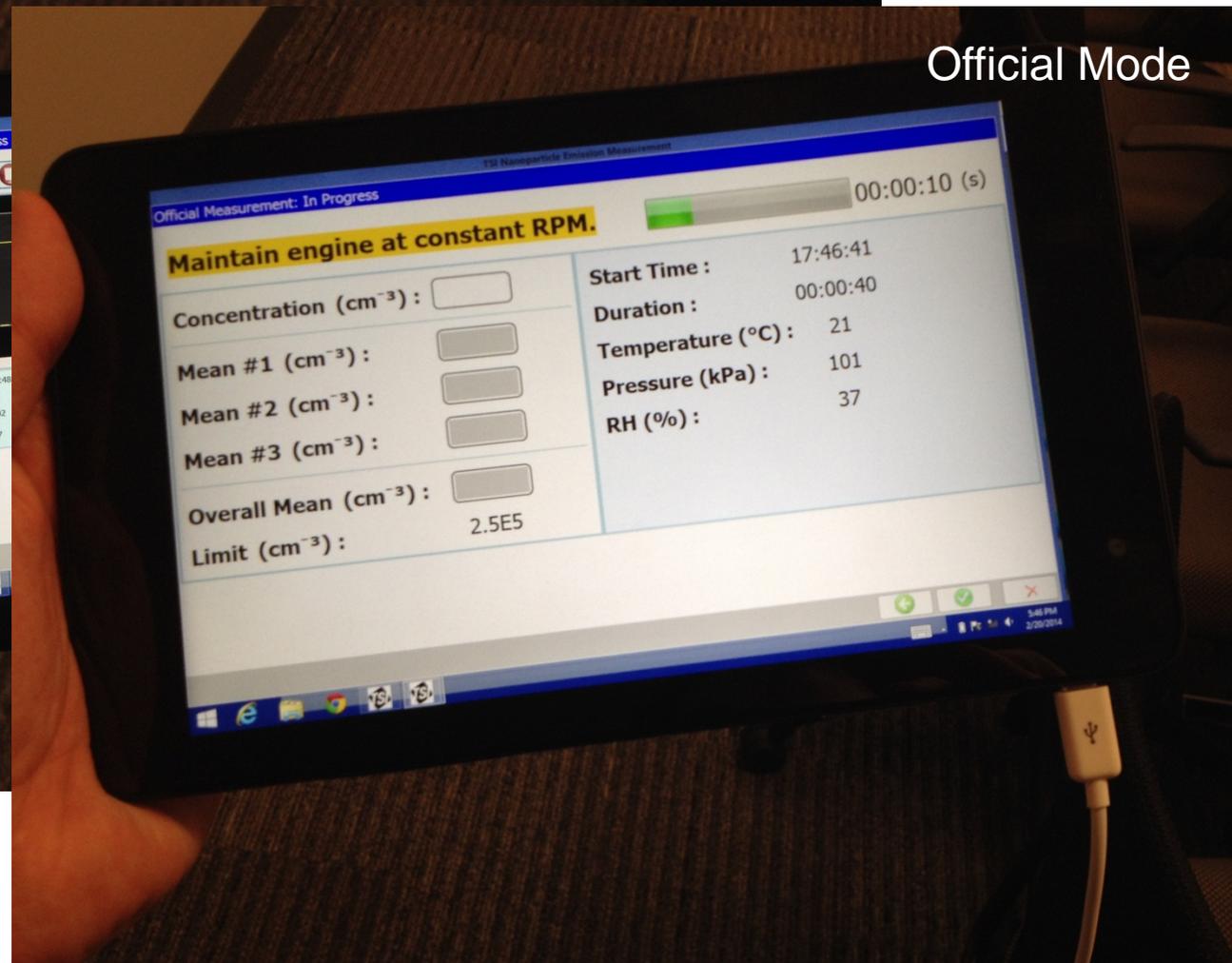
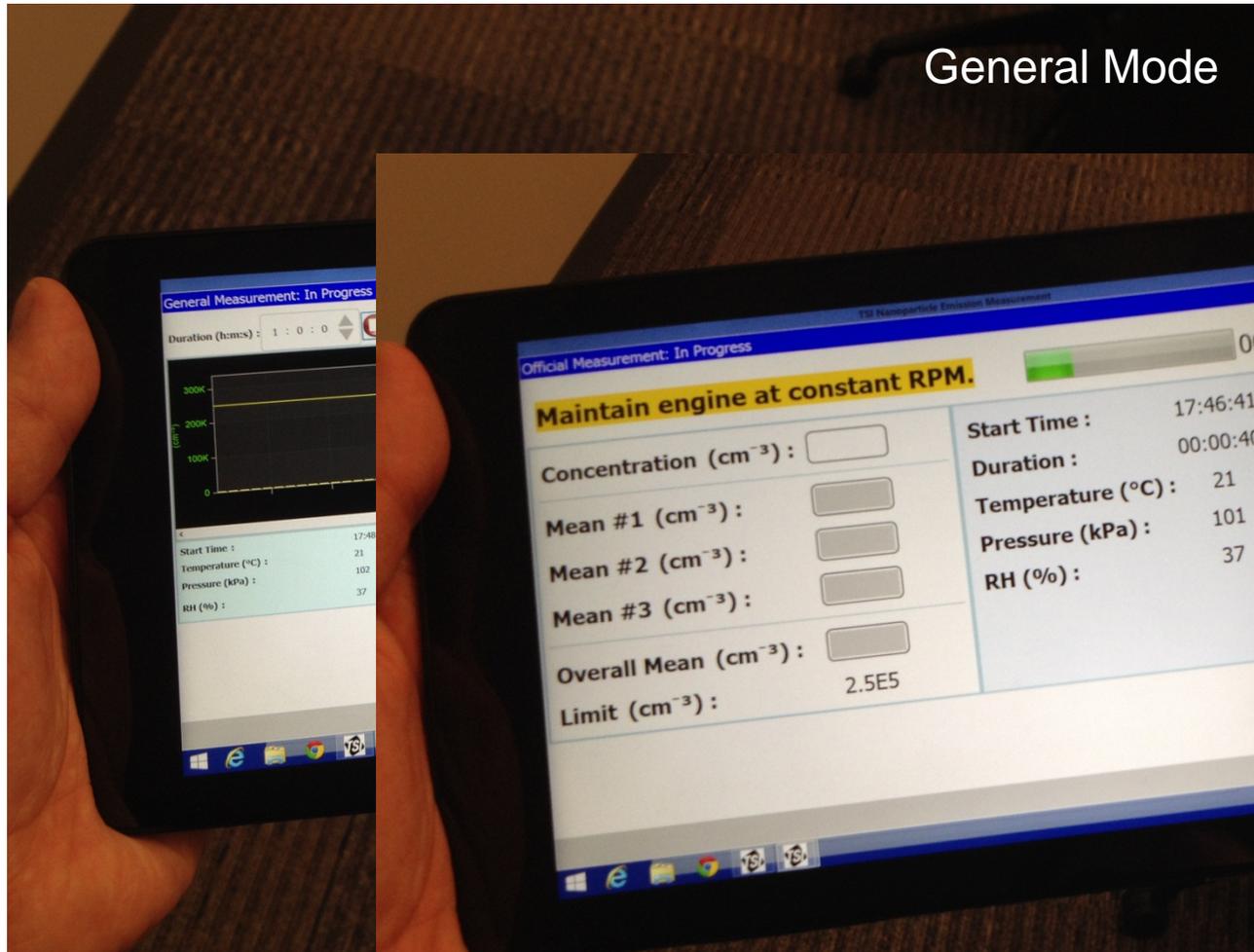
- + Integrated, 10:1 probe-dilution
- + Dried, recirculating dilution air
- + 1 micron cyclone with water trap
- + Catalytic stripper
- + Isopropyl-based condensation particle counter
- + Powered e.g. by a Windows 8 Pro tablet and software application
- + General purpose & official Swiss test mode



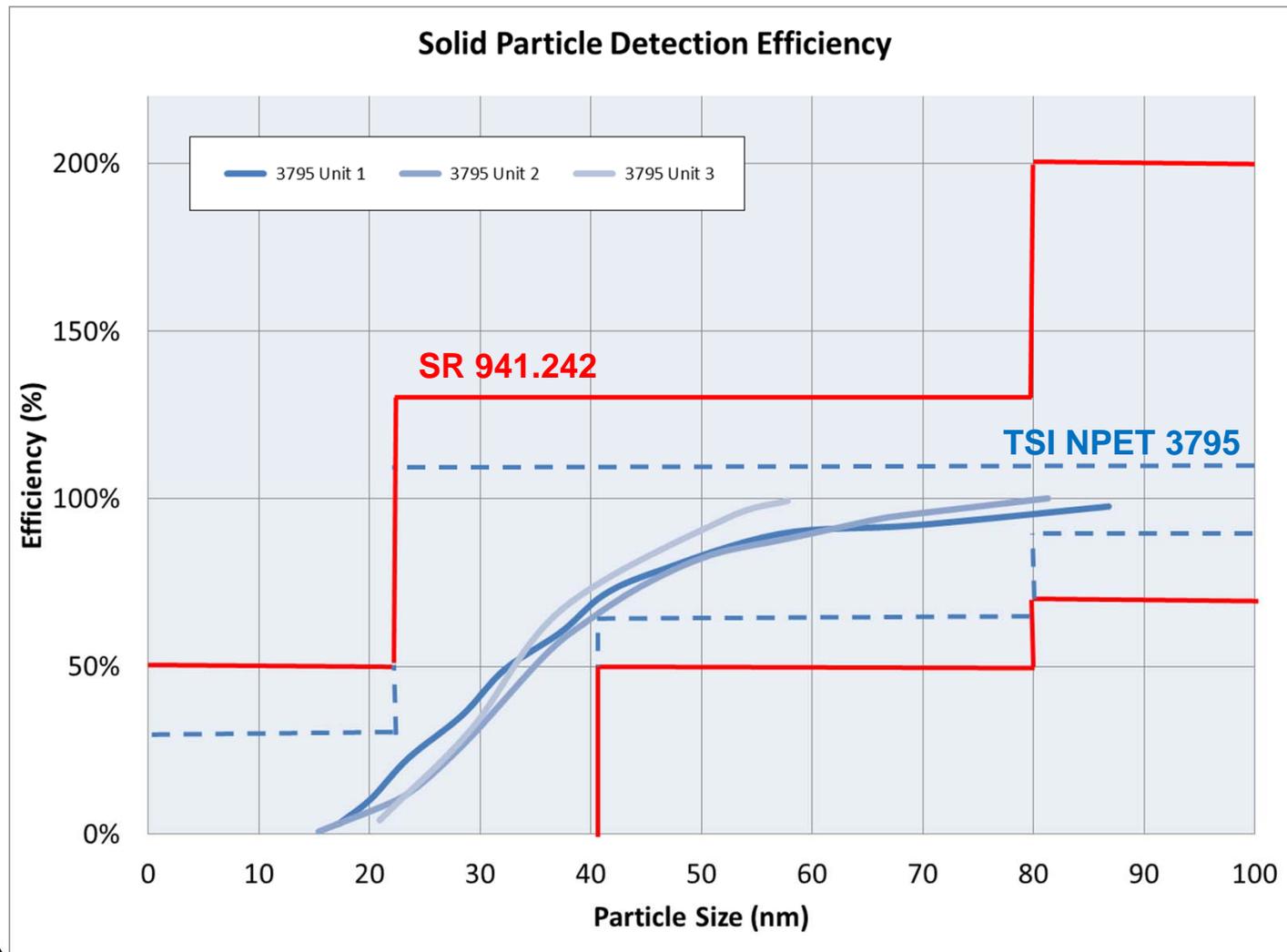
General & Official Operation Modes



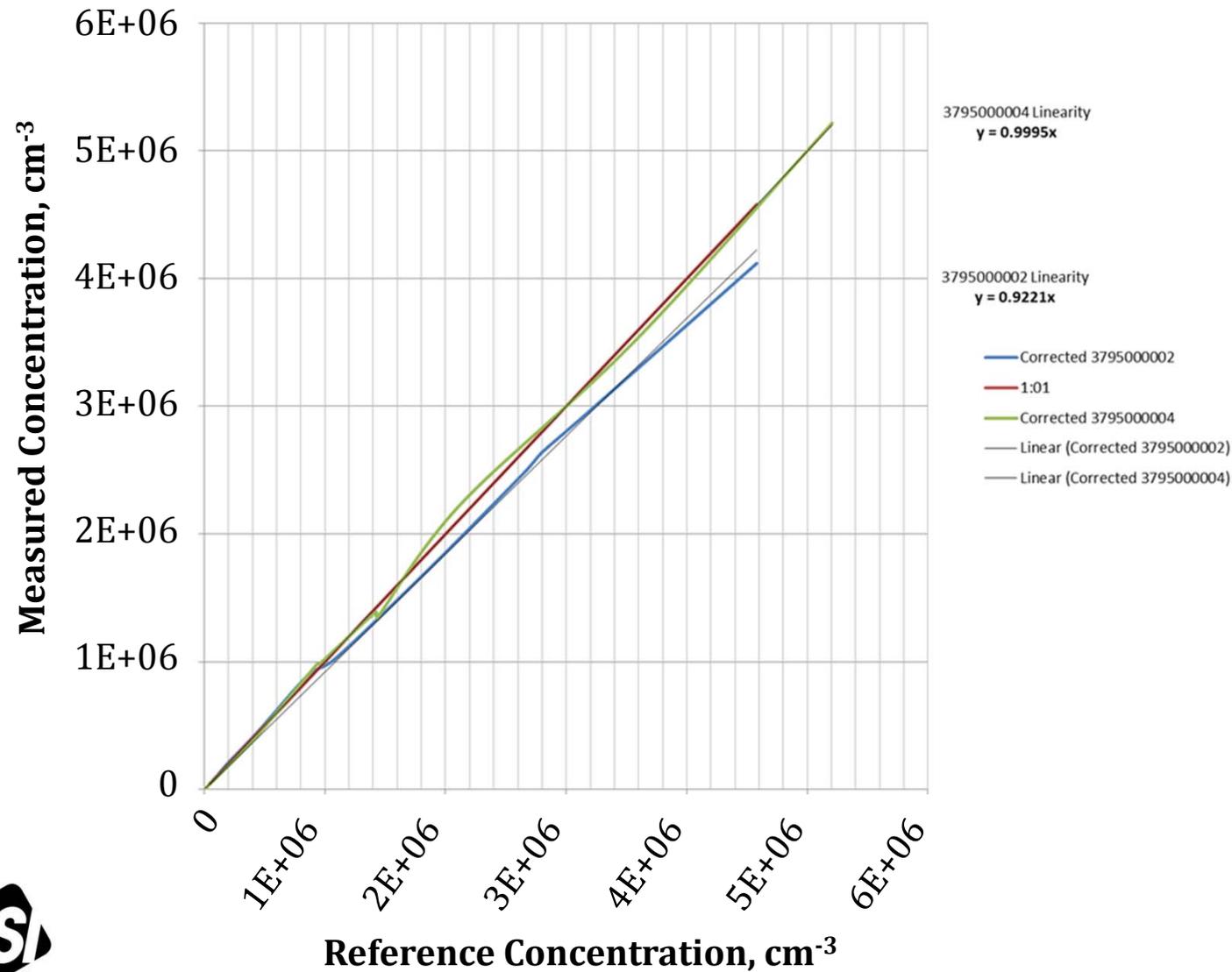
General & Official Operation Modes



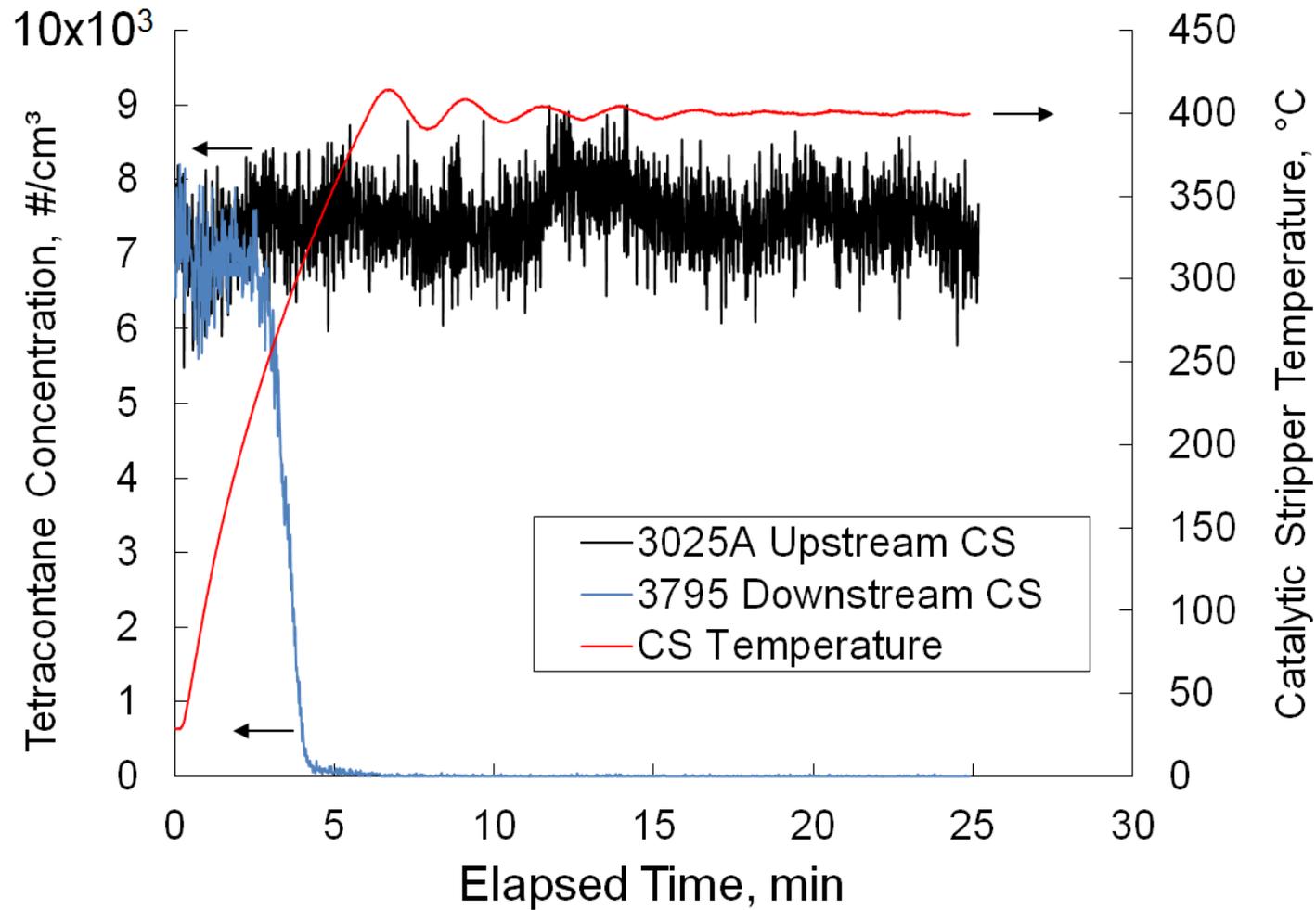
Solid Particle Detection Efficiency



Concentration Range and Linearity



Volatile Particle Removal



Prototype Conformity Tests at METAS

Test	Requirement	NPET Prototype
Efficiency 23 nm CAST 23 nm, GSD = 1.48	$[E = \frac{C_{Dut}}{C_{CPC}}] < 0.5$	E = 0.47
Efficiency 41 nm CAST 41 nm, GSD = 1.57	$0.5 < [E = \frac{C_{Dut}}{C_{CPC}}]$	E = 0.84
Efficiency 80 nm CAST 83 nm, GSD = 1.54	$0.7 < [E = \frac{C_{Dut}}{C_{CPC}}] < 1.3$	E = 1.13
Efficiency 200 nm CAST 192 nm, GSD = 1.56	$[E = \frac{C_{Dut}}{C_{CPC}}] < 2.0$	E = 1.23
Endurance 6 h; CAST 80 nm w/o VPR, $C \approx 5e6 \text{ cm}^{-3}$	$0.7 < [E = \frac{C_{Dut}(t)}{C_{CPC}(t)}] < 1.3$	t = 0 h: E = 1.05 t = 6 h: E = 0.99
Official measurement CAST 80 nm, $C_1 \approx 1e5 \text{ cm}^{-3}, C_2 \approx 5e5 \text{ cm}^{-3}$	$0.7 < [E = \frac{C_{Dut}}{C_{CPC}}] < 1.3$	$C_1 = 1.27e5 \text{ cm}^{-3}$: E = 1.075 $C_2 = 5.57e5 \text{ cm}^{-3}$: E = 1.055
Tetracontane removal 30 nm, $C_{Tc} = 10^5 \text{ cm}^{-3}$	$[E = \frac{C_{Dut}}{C_{Tc}}] < 0.05$	$\frac{1.14}{7.2e5} = 0.0000016$

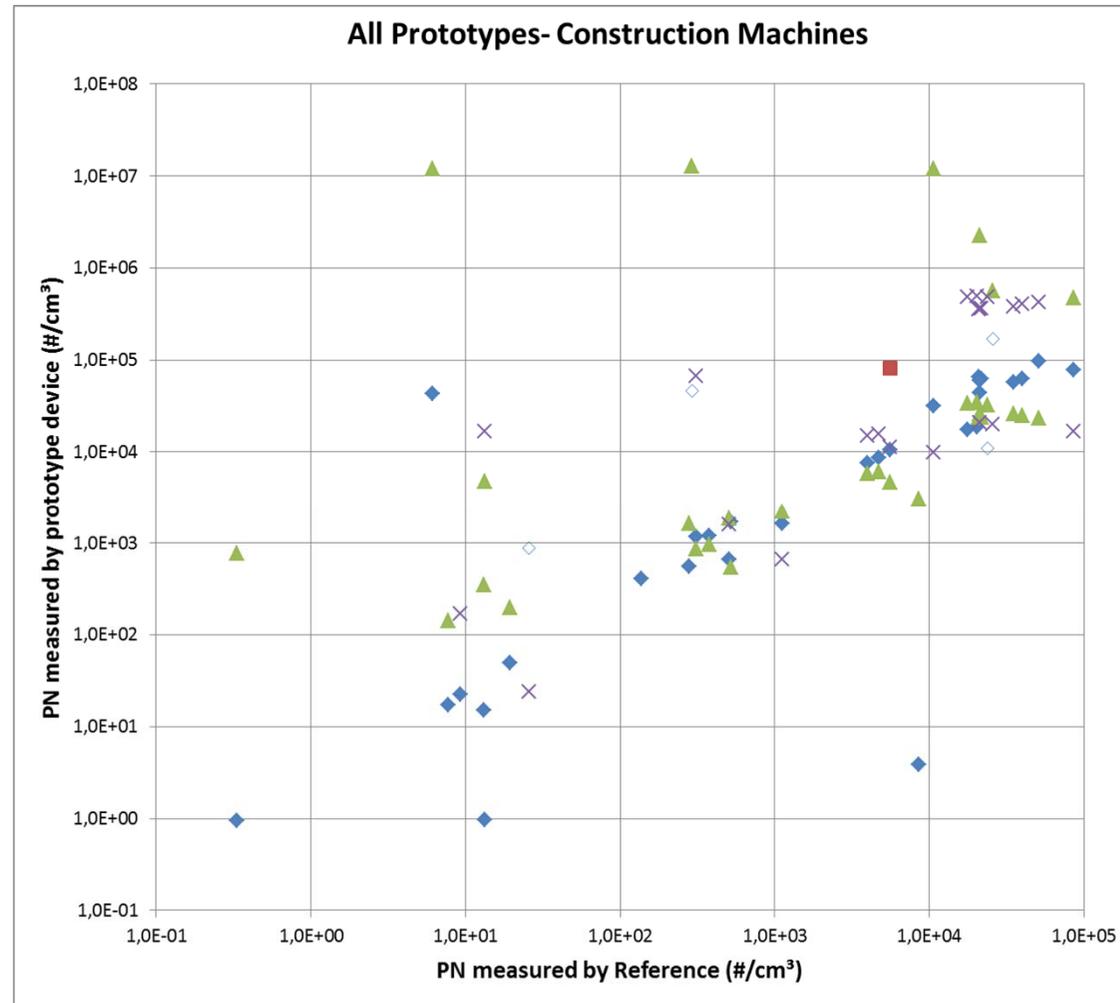


Prototype Conformity Tests at METAS continued

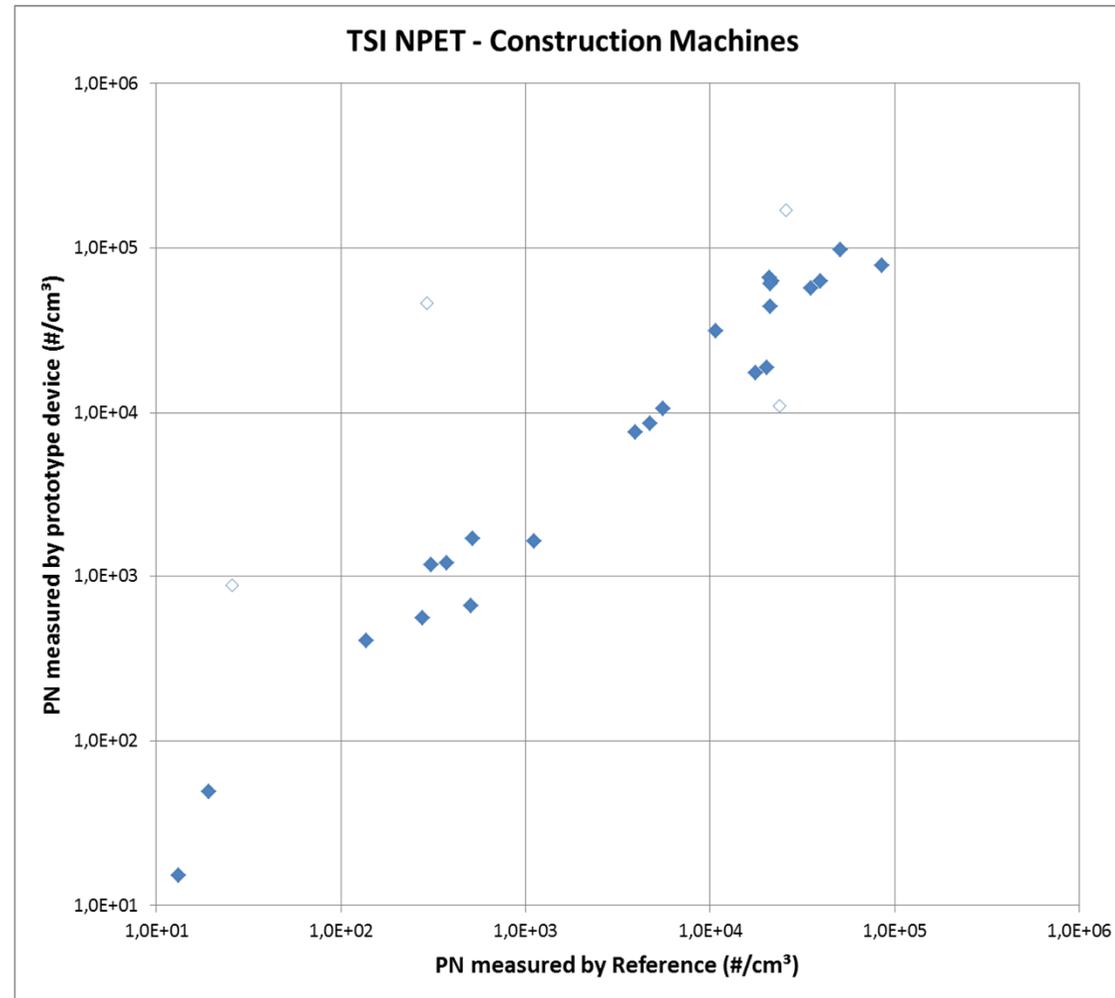
Test	Requirement	NPET Prototype
Ambient pressure dependence $P \approx P_{\text{atm}} \pm 10 \text{ kPa}$	$0.7 < [R = \frac{C_{Dut}(P)/C_{CPC}(P)}{C_{Dut}(P_{\text{amb}})/C_{CPC}(P_{\text{amb}})}] < 1.3$	$P_1 = 86 \text{ kPa}: R = 1.04$ $P_{\text{amb}} = 95 \text{ kPa}: R = 1.00$ $P_2 = 104 \text{ kPa}: R = 0.85$
Amb. low temp. dependence $T_1 = T_{\text{amb}}, T_2 = -8^\circ\text{C}$	$0.7 < [R = \frac{C_{Dut}(T)/C_{CPC}(T)}{C_{Dut}(T_{\text{amb}})/C_{CPC}(T_{\text{amb}})}] < 1.3$	$T_{\text{amb}} = 24^\circ\text{C}: R = 1.00$ $T_2 = -8^\circ\text{C}: R = 0.84$
Amb. high temp. dependence $T_1 = T_{\text{amb}}, T_2 = 38^\circ\text{C}$	$0.7 < [R = \frac{C_{Dut}(T)/C_{CPC}(T)}{C_{Dut}(T_{\text{amb}})/C_{CPC}(T_{\text{amb}})}] < 1.3$	$T_{\text{amb}} = 24^\circ\text{C}: R = 1.00$ $T_2 = 38^\circ\text{C}: R = 0.73$
Step response $T_{10\% - 90\%}$	$T_{10\% - 90\%} < 5 \text{ s}$	$T_{10\% - 90\%} < 4 \text{ s}$
Time Lag $T_{0\% - 70\%}$	$T_{0\% - 70\%} < 10 \text{ s}$	$T_{0\% - 70\%} < 7 \text{ s}$



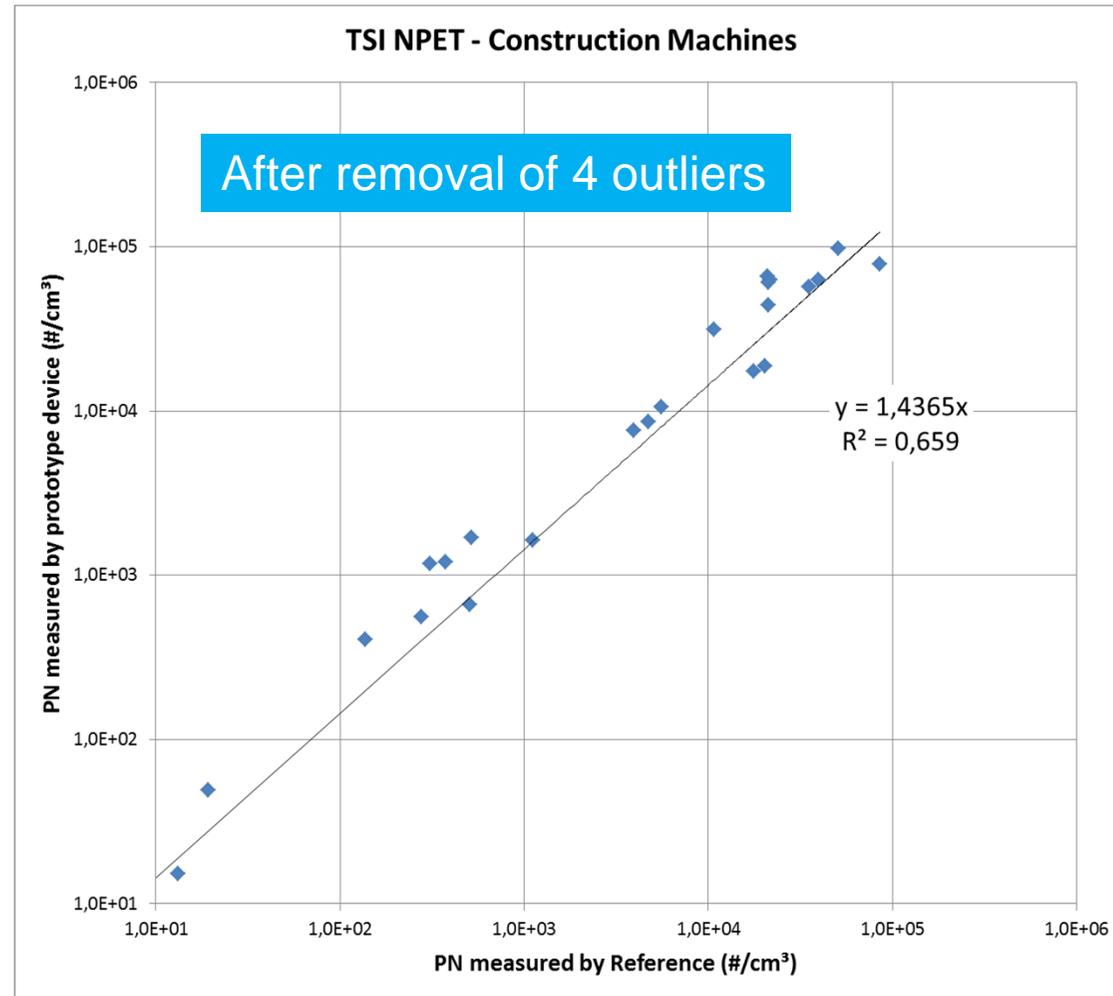
Results of First Field Tests by BAFU Construction Machines



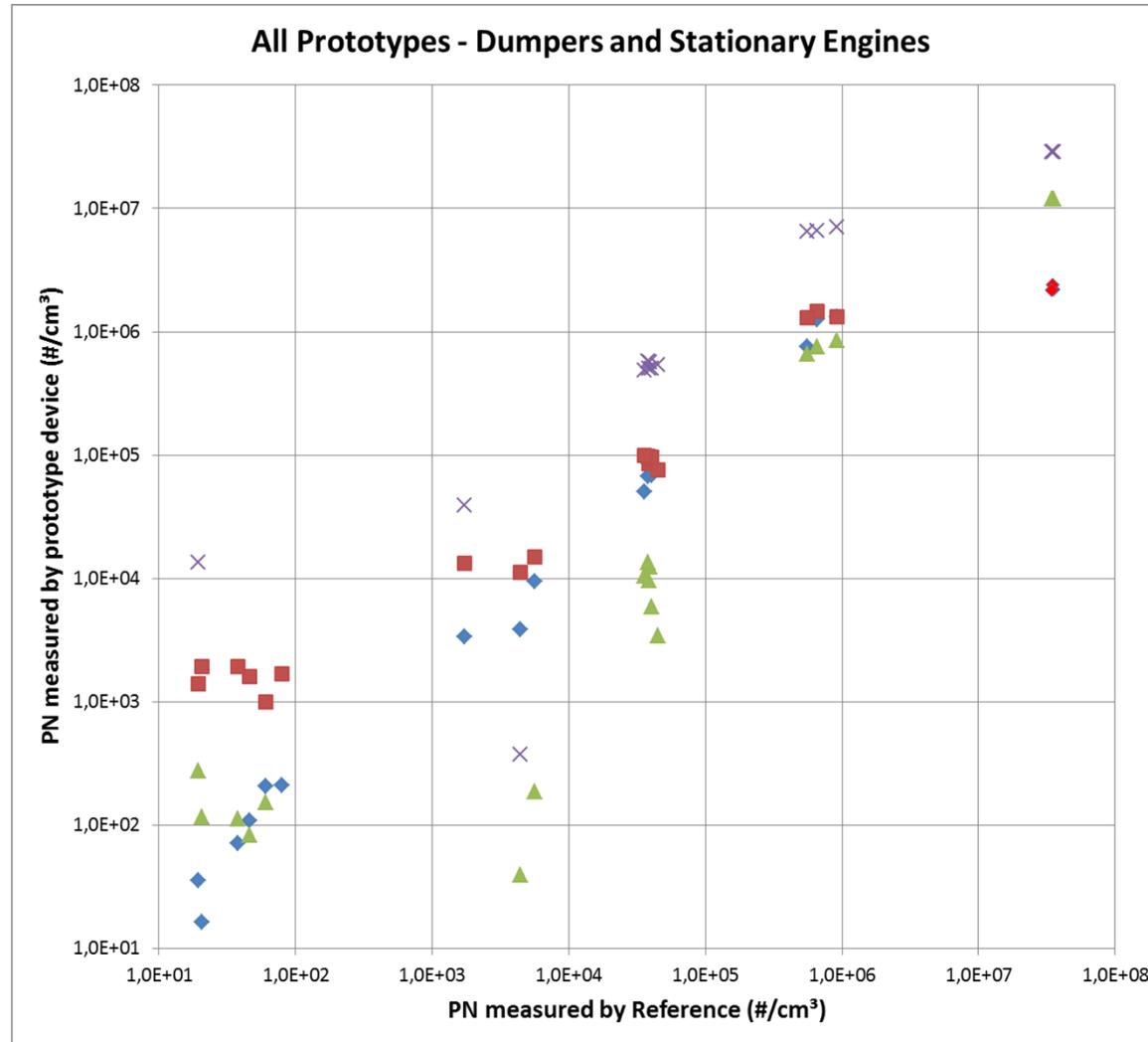
Results of First Field Tests by BAFU Construction Machines



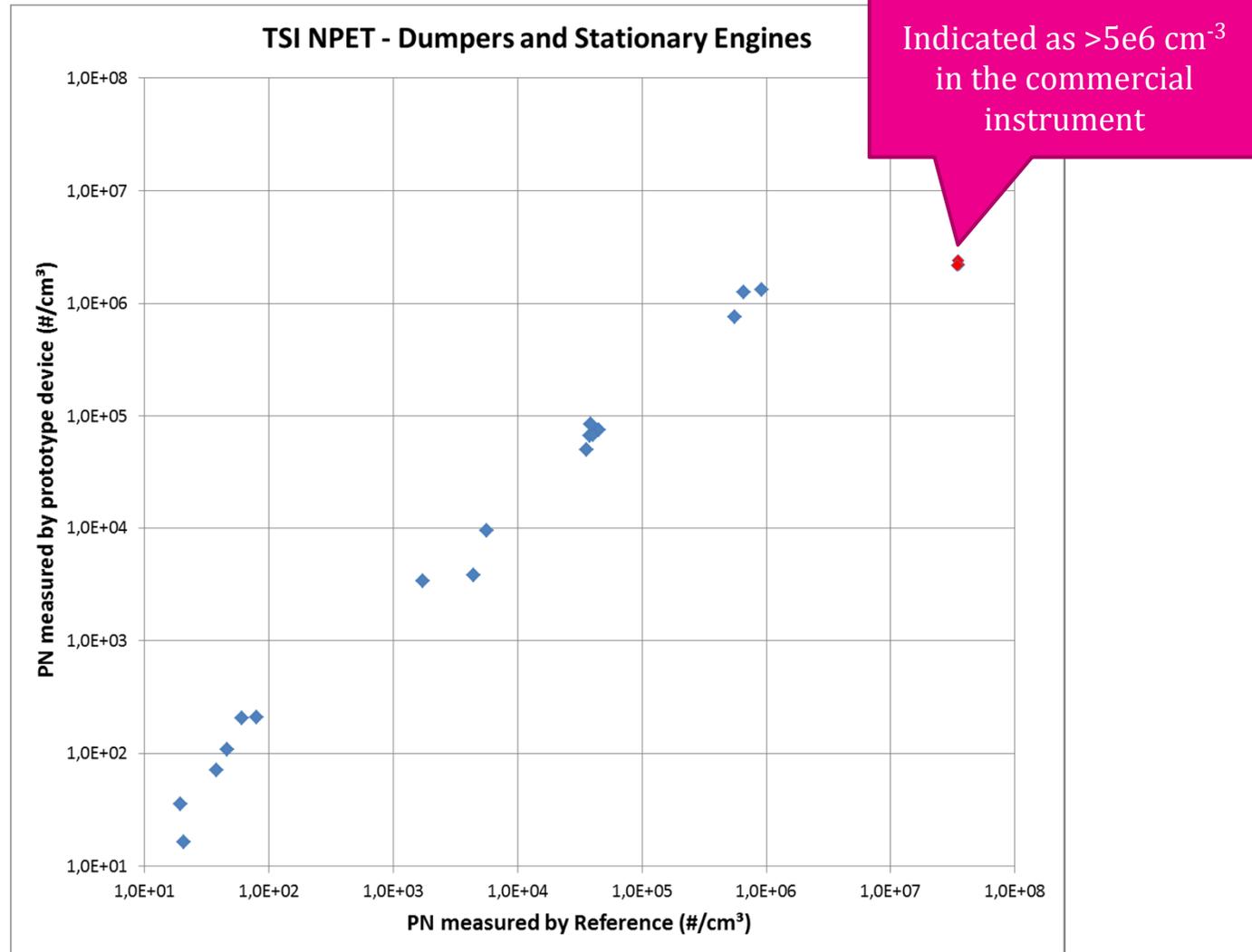
Results of First Field Tests by BAFU Construction Machines



Results of First Field Tests by BAFU Dumpers & Stationary Engines



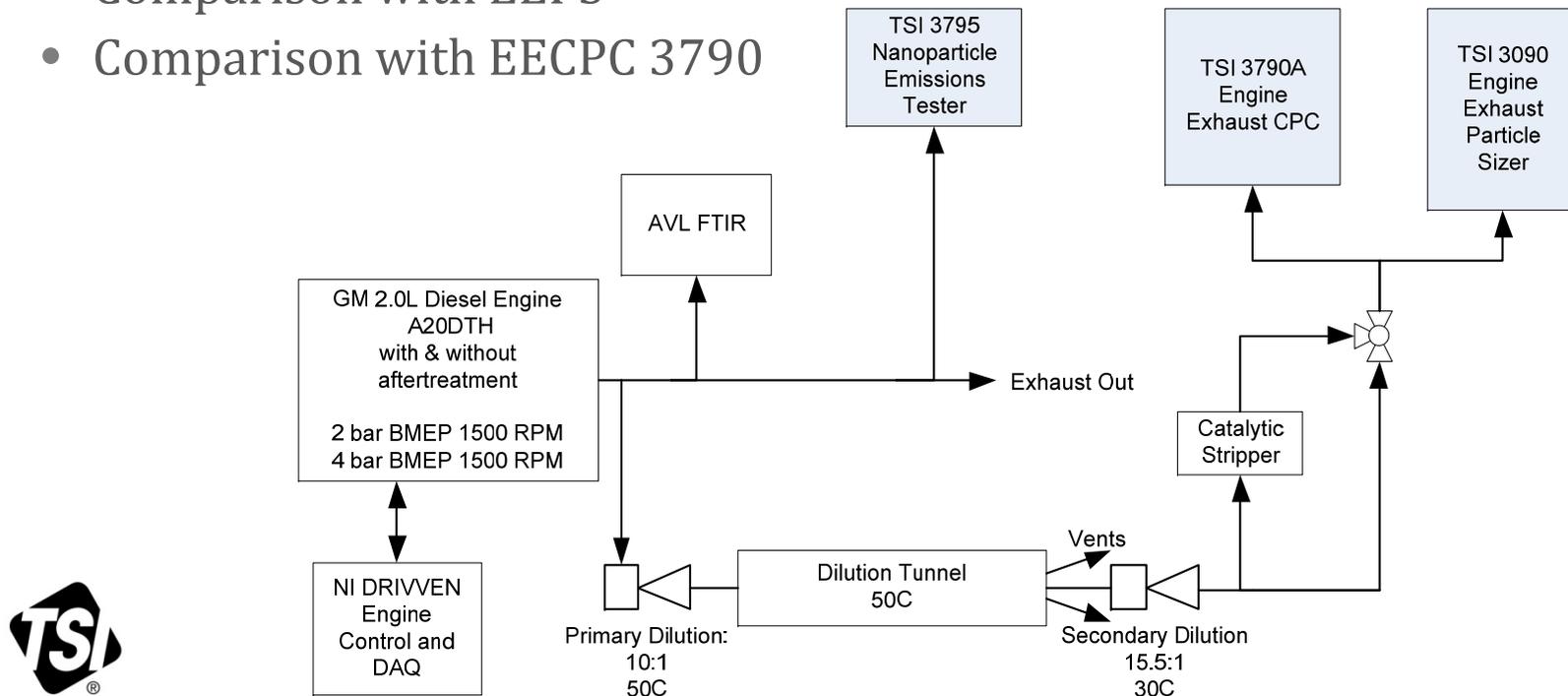
Results of First Field Tests by BAFU Dumpers & Stationary Engines



Measurement Examples

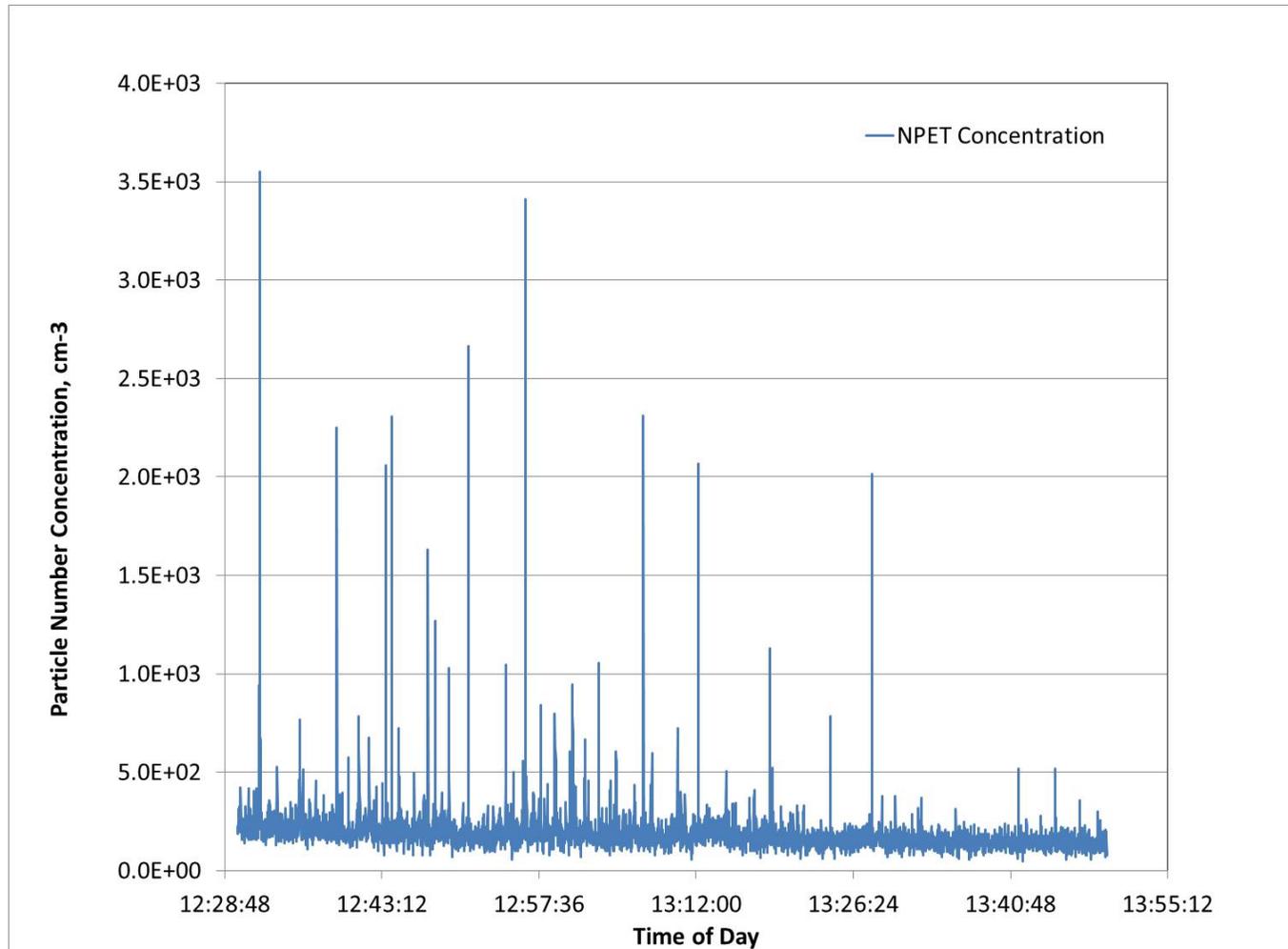
+ Data were taken at U of Minnesota (Dave Kittelson & Will Northrup)

- Engine held at a simulated high idle
- Regeneration event
- Comparison with EEPS
- Comparison with EECPC 3790

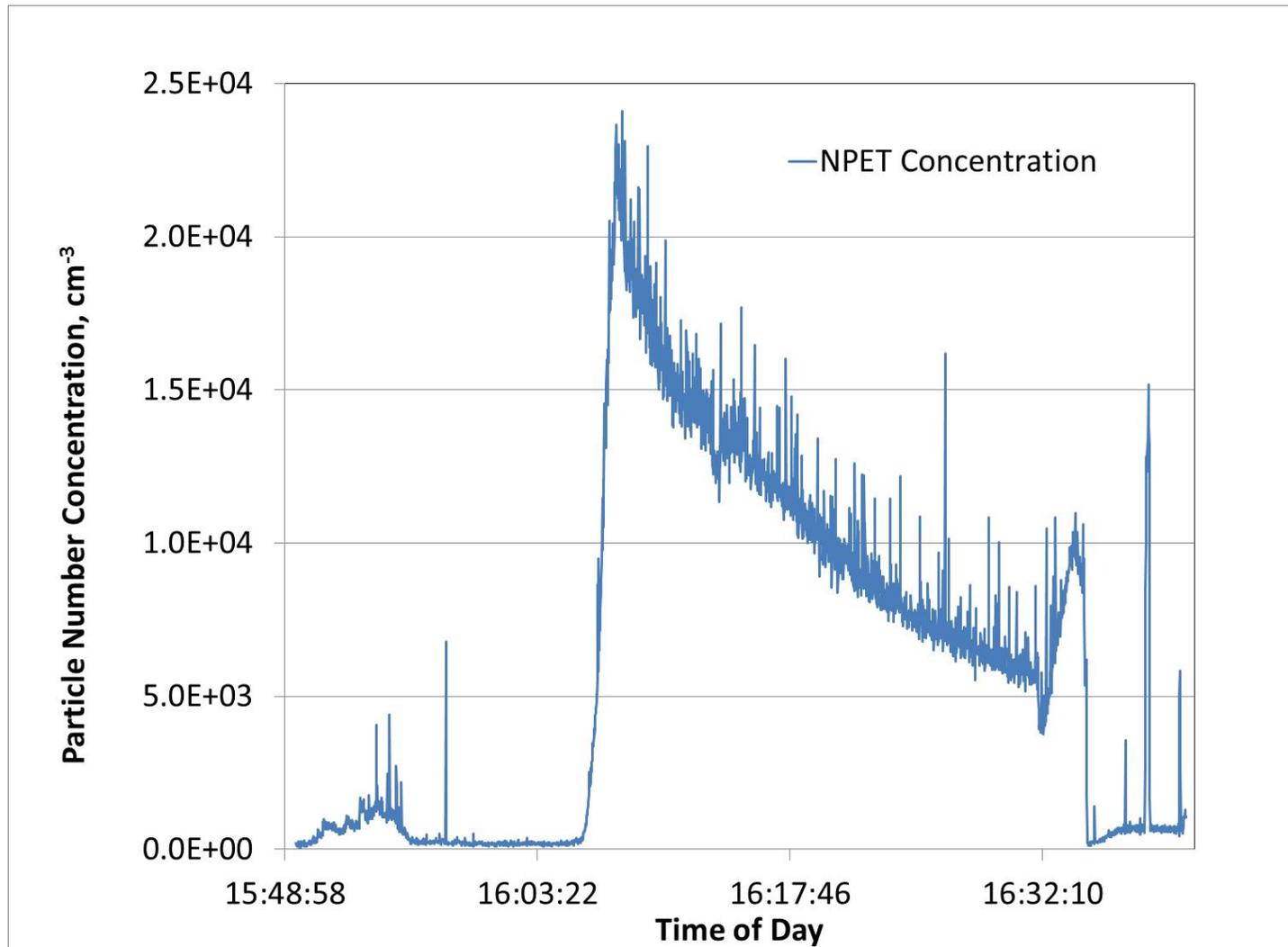


Simulated High Idle

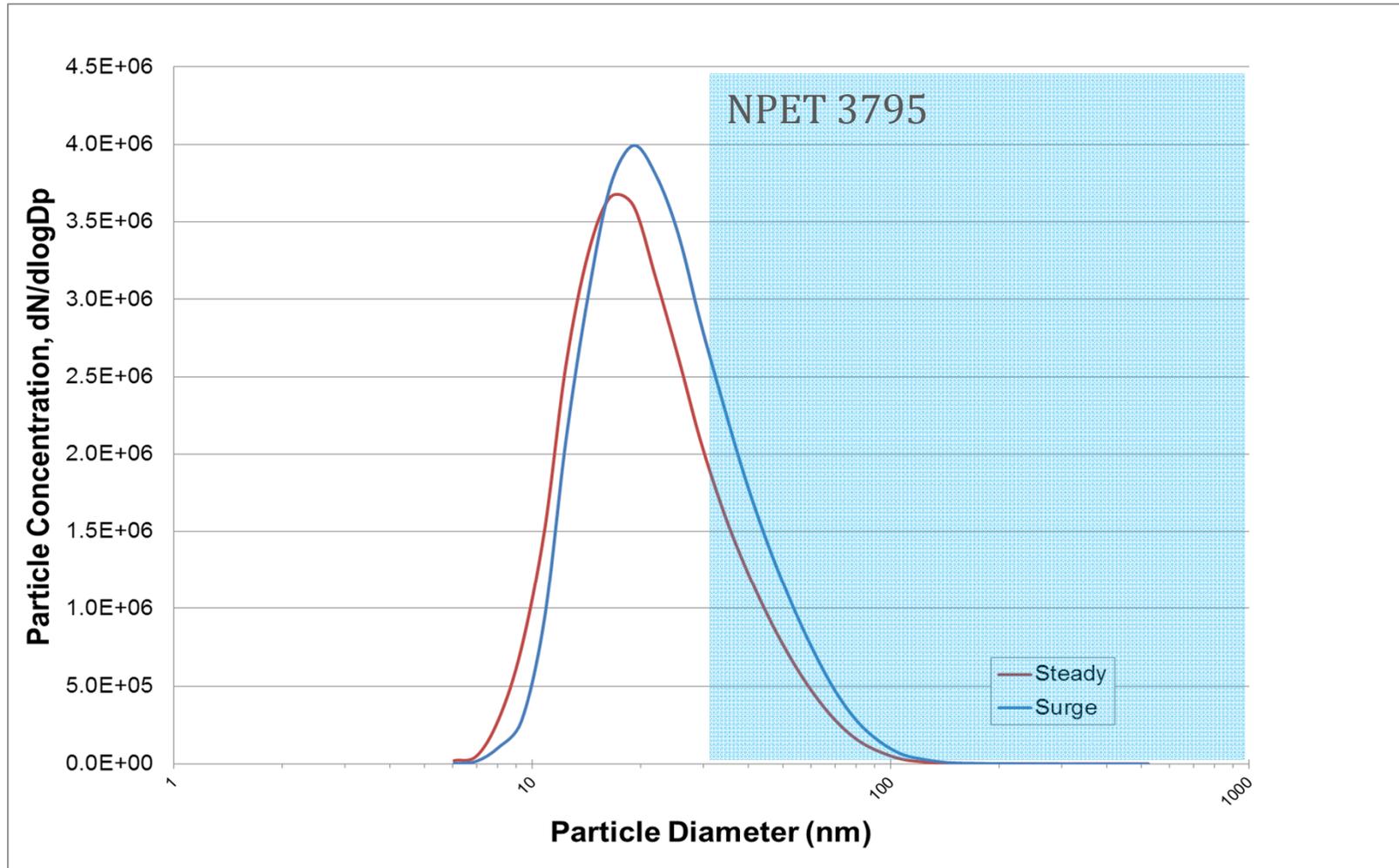
Mean Concentration = 193 cm^{-3}



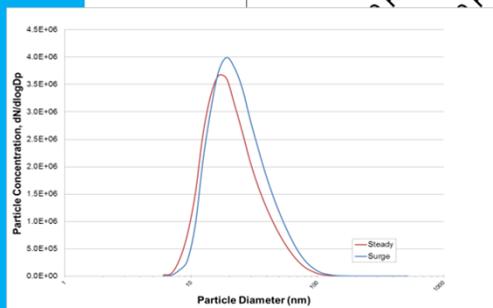
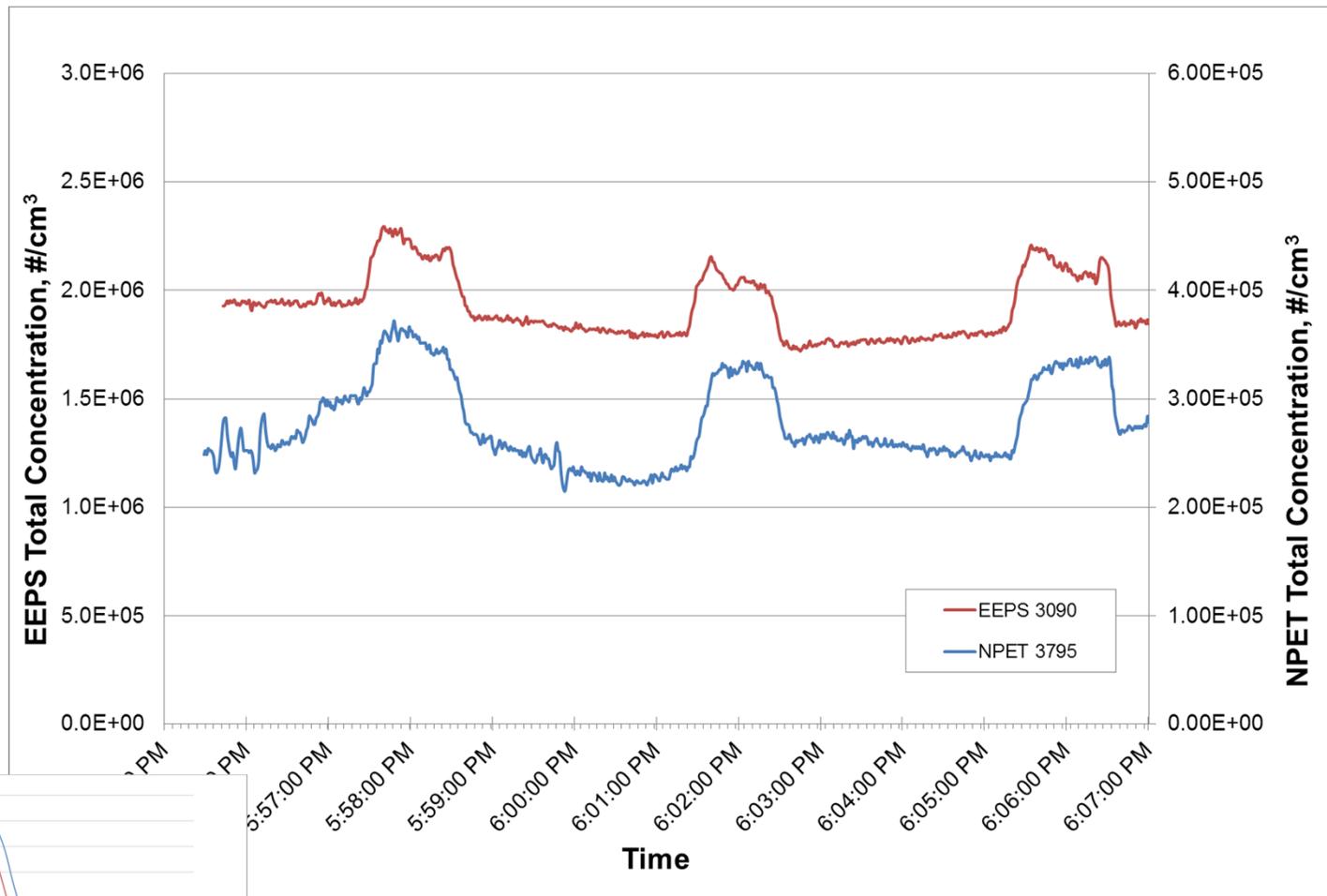
Regeneration Event



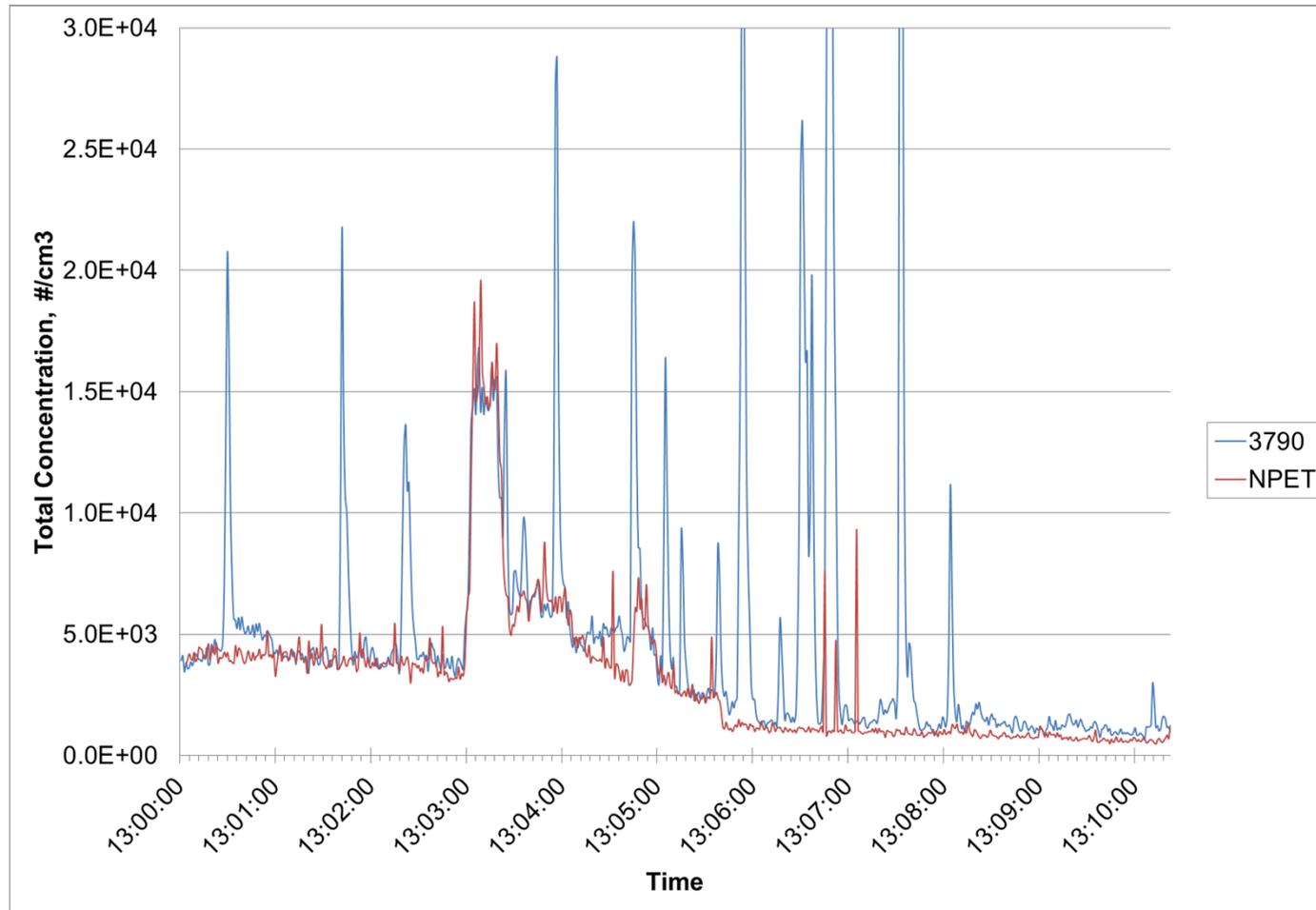
Comparison with EEPS



Comparison with EEPS



Engine Startup, DPF Out



Conclusions

- + Robust, portable instrument for field measurements
- + Conformity to Swiss SR 941.242
- + Good linearity of response between ~ 200 and $5e6$ particles per cm^3 in official measurement mode
- + Distribution, customer service and support in Switzerland by Deltatech in Hunzenschwil
- + We are ready to accept your orders



Thank you very much!

Questions ?

For additional information:

hans-georg.horn@tsi.com

www.tsi.com

www.deltatech.ch

